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A PHOTOMETRIC INVESTIGATION OF COMET P/ENCKE

Report No. 1

FINAL REPORT under JPL Contract BP-724891



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Abstract

Photometric observations of Comet P/Encke were obtained on October 9 and 10, 1980, with the 2.2-meter telescope at Mauna Kea Observatory. Additional measurements were made using the 0.6-meter reflector at Lowell Observatory on November 6 and 8, 1980. Production rates of OH, CN, C₂, and C₃ were determined.

Introduction

A photometric investigation of Comet P/Encke was undertaken using the 2.2-meter telescope at Mauna Kea Observatory and the 0.6-meter telescope at Lowell Observatory. The program had two primary scientific objectives: (1) measurement of the production rates of OH, CN, C₂, and C₃ as a function of heliocentric distance and (2) determination of the comet's rotational period by searching for periodic brightness variations in the inner coma, as had previously been attempted by Fay and Wisniewski (1978) for Comet d'Arrest. The first objective was to be accomplished using equipment and techniques developed for the purpose over the last few years (e.g., A'Hearn and Millis, 1980; Millis and A'Hearn, 1981). Synoptic observation by observers in the Canary Islands; Cambridge, Massachusetts; Flagstaff, Arizona; and Mauna Kea were planned for the study of the comet's rotation.

Technical Discussion

In Figure 1 we have plotted the elongation, predicted total magnitude, and number of hours per night with $\sec z < 2$ for Comet Encke as a function of date. Note that during October 1980 the comet was expected to brighten rapidly from 11 mag to 7.5 mag, while the number of hours per night that the comet could be observed decreased rapidly. Towards the end of the month, the phase of the Moon also became unfavorable.

Observing time early in October was requested in order to maximize the number of hours per night that Encke was observable. Continuous observational coverage for a period of several hours was essential for the study of rotation. Experience with other comets led us to believe that at its predicted brightness, Encke would be easily within reach of both the 2.2-meter and 0.6-meter telescopes at Mauna Kea Observatory. Four nights on the 2.2-meter telescope (October 7 through 10) were allocated for our program, along with an additional 13 nights on the 0.6-meter Planetary Patrol telescope.

By late September, it became evident that Comet Encke was not going to be nearly as easy an object as expected. Several efforts to visually locate it with the 1.8-meter and 1.0-meter telescopes in Flagstaff were unsuccessful. Reports of similar difficulties were received from other observatories.

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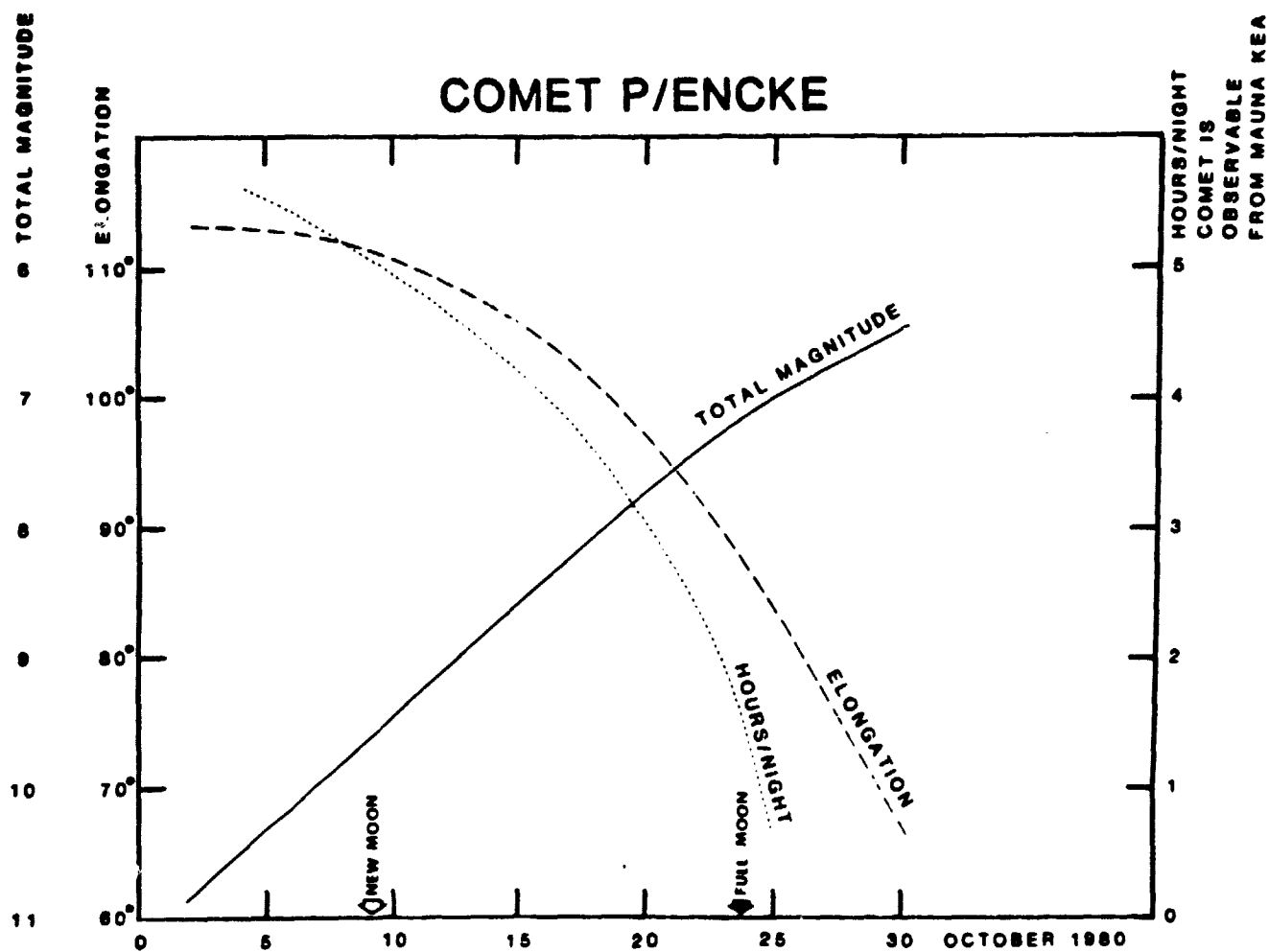


Figure 1. Parameters affecting planned observations of Comet P/Encke during October 1980.

The problem apparently was due primarily to Encke's large angular extent and to the very diffuse character of its coma. By mid-October, visual observers were reporting coma diameters of 10 arcmin (Marsden, 1980), yet long-exposure photographs showed only a weak coma with an unresolved nuclear condensation (e.g., Shao and Schwartz, 1980). Figure 2 shows a 5-minute exposure on Comet Encke obtained by Alan Stockton on 6 October 1980 with an image tube on the Mauna Kea 2.2-meter telescope. The fan-shaped coma could not be seen when viewing directly through the telescope, while the nucleus was distinguishable from a star only by its rapid motion. Encke was barely visible in the 0.6-meter telescope on 5 October 1980, but it was so faint and diffuse that photometry was not possible.

The first two nights of the 2.2-meter run were cloudy. On the third night, the brightness of Comet Encke was monitored continuously for four hours through three filters: V of the UBV system, a 250-Å-wide (FWHM) interference filter centered at 4850 Å, and a 260-Å-wide (FWHM) filter at 5120 Å. The V light curve is shown in Figure 3. Each point represents the mean of six 10-second integrations through a 10-arcsec-diameter aperture centered on the nucleus. The signals from the comet and the sky background were approximately equal. based on photon statistics alone, an uncertainty of ± 0.03 mag would be expected in the plotted points. Judging from the repeatability of consecutive measurements, the actual error bars are estimated to

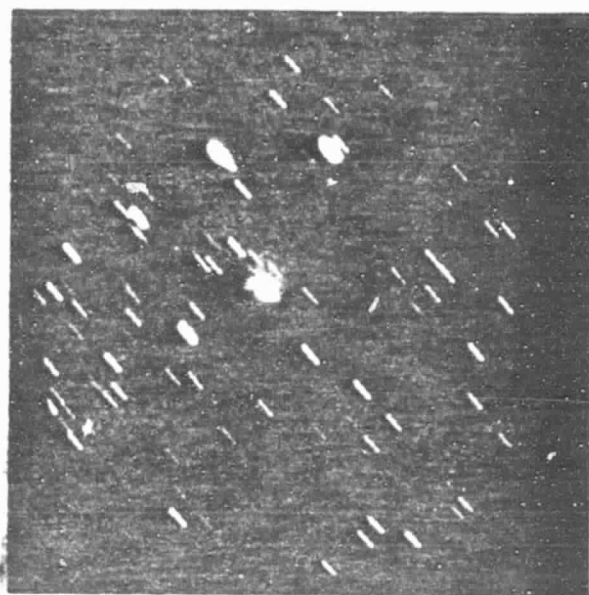


Figure 2. Direct, image tube photograph of Comet P/Encke taken with the 2.2-meter telescope at Mauna Kea. The scale of the print is approximately 5 arcsec/mm.

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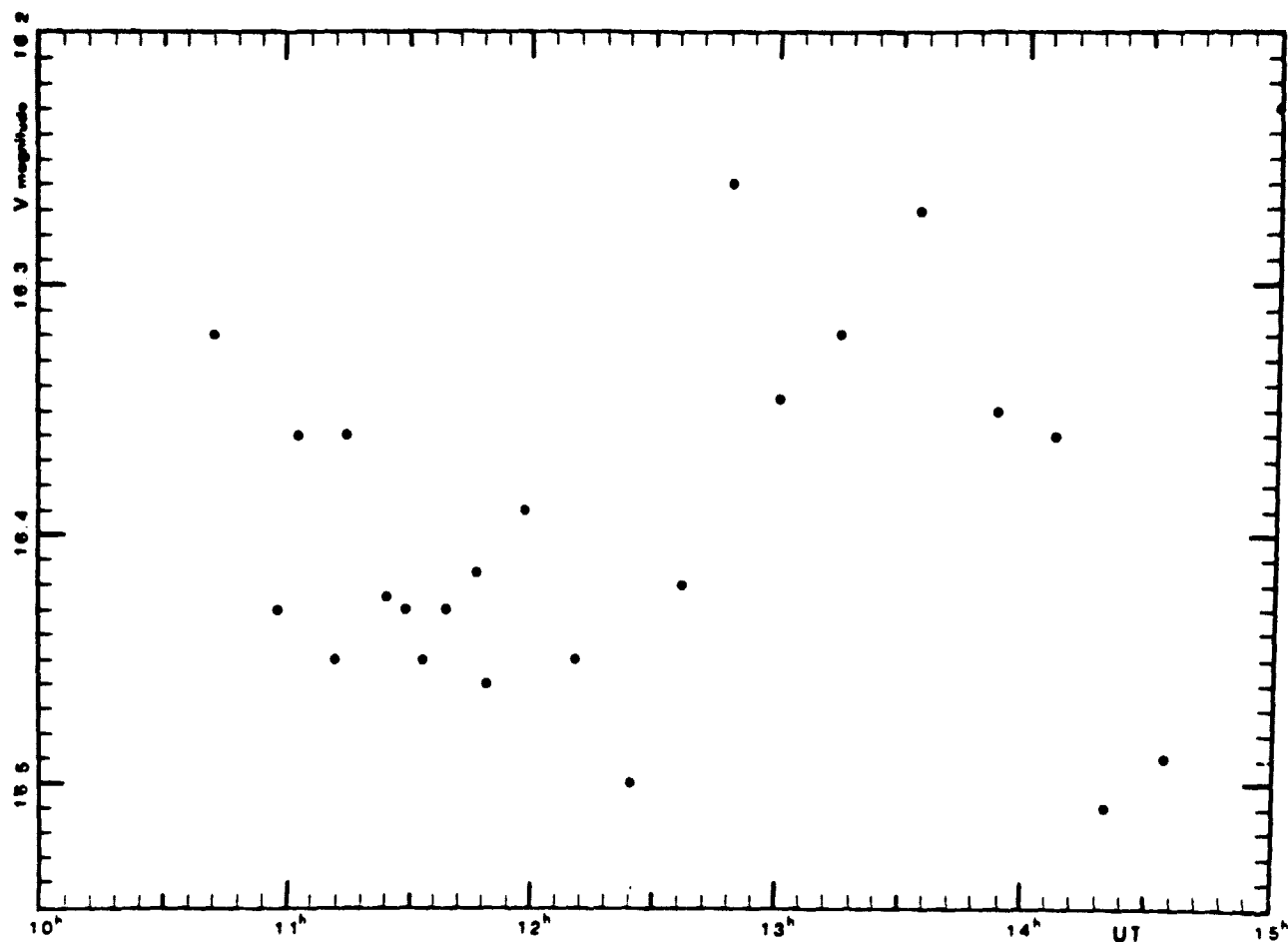


Figure 3. V magnitude of Comet P/Encke through a 10-arc-sec-diameter aperture centered on the nucleus plotted against UT on 9 October 1980. Error bars are typically ± 0.06 mag.

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closer to twice that amount. Possible causes of the increased error are inclusion of unseen stars in the entrance aperture and centering errors. Two comparison stars, BD+51°1040 ($V = 10.34$ mag) and BD+51°1038 ($V = 9.95$ mag), were used. These stars were constant during the four-hour period of observation to within better than ± 0.003 mag.

While the observations in Figure 3 perhaps show some evidence of intrinsic brightness variation, no believable period can be derived without independent confirmation from other sites. Unfortunately, efforts to do coordinated photometry of this comet from Tenerife, Agassiz, and Flagstaff were unsuccessful. Hence, the only result that can be stated with complete confidence is that the mean V magnitude of the nuclear region of Comet Encke on 9 October 1980 was 16.40 ± 0.05 mag. For comparison, Yeomans (1980) predicted a nuclear magnitude of 16.8 mag.

October 10, the final night of the 2.2-meter run, was devoted to narrowband photometry. Measurements were made through a standard set of interference filters isolating emission bands of OH, CN, C_2 , and C_3 along with selected regions of continuum. The resulting fluxes are listed in Table I together with measurements from the Lowell Observatory 0.6-meter telescope on November 6 and 8. On the later two dates, Comet Encke was much brighter but was visible only briefly in the predawn sky. Production rates of the various molecular species

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Table I.

Comet Encke

Date:	10 October 1980	6 November 1980	8 November 1980
Telescope:	MKO 2.2-meter	Lowell 0.6-meter	Lowell 0.6-meter
Diaphragm Diameter (arcsec):	10	111	79
r (a.u.)	1.230	0.789	0.752
Δ (a.u.)	0.451	0.330	0.354
Log F (OH)	-12.246 \pm 0.051	-9.027 \pm 0.036	-9.981 \pm 0.090
Log F _{λ} (3300)	-15.143 \pm 0.016	-13.050 \pm 0.124	-12.970 \pm 0.010
Log F _{λ} (3675)	-15.003 \pm 0.031	-12.624 \pm 0.060	-13.878
Log F (CN)	-12.453 \pm 0.009	-9.263 \pm 0.003	-9.494 \pm 0.010
Log F (C ₂)	-12.643	-10.040	-10.153 \pm 0.120
Log F _{λ} (4120)	-14.460	-	-12.682
Log F (C ₂)	-12.539 \pm 0.015	-9.212	-9.366
Log F _{λ} (5240)	-15.123 \pm 0.032	-	-

are listed in Table II. Observing and reduction techniques, passbands, and standard stars were the same as described previously by A'Hearn, Millis, and Birch (1979, 1981), A'Hearn and Millis (1980), and Millis and A'Hearn (1981).

Table II.

Comet Encke Production Rates

UT Date (1980)	r (a.u.)	Δ (a.u.)	OH	Log Q CN	C ₂	C ₂
October 10.598	1.230	0.451	27.199	24.551	24.746	24.645
November 6.515	0.789	0.330	27.983	25.406	25.689	25.781
November 8.522	0.752	0.354	27.213	25.353	25.703	25.814

Several points concerning the data in Table II are of interest. The production rate of OH at $r = 0.79$ a.u. reported here agrees well with that observed from IUE at $r = 0.81$ a.u. (A'Hearn, 1981). However, the production rate of this radical apparently fell quite steeply between November 6 and November 8. The observations on both dates were repeatable with no evidence of significant observational error. The OH observations listed in Tables I and II are the first to be made for Comet Encke using ground-based photometric techniques.

In Figure 4 the production rate of CN is plotted against heliocentric distance. The cross represents a preperihelion measurement by A'Hearn, Millis, and Birch (1979) during the 1977 apparition of Comet Encke. The variation of production rate with heliocentric distance is very steep with an $r^{-4.1 \pm 0.5}$ dependence giving the best-fitting line shown in the figure. Similarly steep power laws are observed over this range in heliocentric distance for the other species and for the total magnitude (Mumma, 1976).

New Technology

The research program described here involved no reportable items of new technology.

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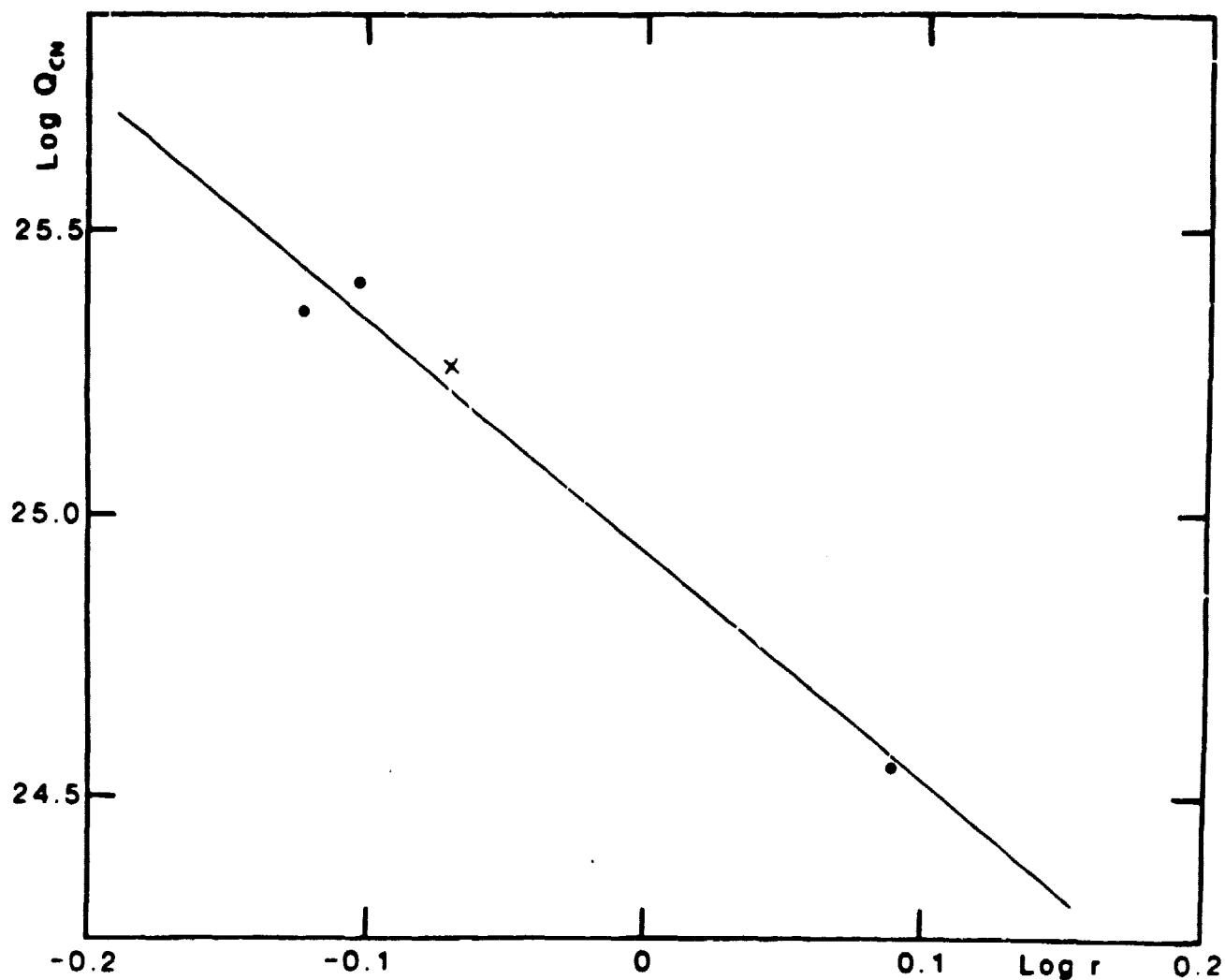


Figure 4. Production rate of CN in Comet P/Encke as a function of heliocentric distance. Filled circles represent the current observations. The cross is from A'Hearn, Millis, and Birch (1979). The straight line was fitted to the data by least squares and corresponds to an $r^{-4.1}$ dependence of production rate on distance.

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References

- A'Hearn, M. F. (1981). Private communication.
- A'Hearn, M. F., and Millis, R. L. (1980). Abundance correlations among comets. Astron. J. 85, 1528-1537.
- A'Hearn, M. F., Millis, R. L., and Birch, P. V. (1979). Gas and dust in some recent periodic comets. Astron. J. 84, 570-579.
- A'Hearn, M. F., Millis, R. L., and Birch, P. V. (1981). Comet Bradfield (1979X): The gassiest comet? Astron. J., in press.
- Fay, R. D., and Wisniewski, W. (1978). The lightcurve of the nucleus of Comet d'Arrest. Icarus 34, 1.
- Marsden, B. G. (1980). IAU Circular No. 3531.
- Millis, R. L., and A'Hearn, M. F. (1981). Ground-based photometry of comets in the spectral interval 3000 to 3500 Å. In Proceedings of the Workshop on Modern Observational Techniques for Comets. NASA SP, in press.
- Mumma, M. J. (1976). Expected scientific results on ballistic spacecraft missions to Comet Encke during the 1980 apparition. In The Study of Comets. NASA SP-393, page 997.
- Shao, C.-Y., and Schwartz, G. (1980). IAU Circular No. 3526.
- Yeomans, D. (1980). Private communication.